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Basell Poliolefine Italia S.p.A.
Via Pergolesi 25
20124 Milano
ITALIE

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Highly stereoregular polypropylene with improved properties

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"HIGHLY STEREOREGULAR POLYPROPYLENE WITH IMPROVED PROPERTIES"

The present invention relates to crystalline propylene polymers having a high level of chain stereoregularity, in particular a high content of isotactic pentads, having improved processability in the molten state and the process for their preparation.

It is known that, thanks to high stereospecificity levels reached by the Ziegler-Natta catalysts, today one can prepare highly crystalline propylene polymers having high mechanical properties and, therefore, adequate for the manufacture of articles with good stiffness and mechanical resistance, even if they are small and thin. The common used propylene polymers show high enough levels of melt strength, i.e. viscoelasticity in the molten state.

It is known that non-highly enough levels of the melt strength of propylene polymers cause an irregular deformation of the melted mass during the conversion processes with the subsequent problems related to workability.

European patent application 573 862 discloses that the melt strength can be significantly improved by widening the molecular weight distribution of the polymer. According to the patent, the molecular weight distribution is at least 20. Consequently, the workability of highly crystalline propylene polymers improves. However, the thickness profile and consistency of the oriented films obtained from these propylene polymers is still not totally satisfactory.

It has now been found that by using in polymerization, under suitable conditions, a particular combination of Ziegler-Natta solid catalyst components and highly stereoregulating electron-donor compounds (outside donors), it is possible to obtain propylene polymers still characterized by high stiffness and other mechanical properties typical of highly crystalline propylene polymers, but also by an improved workability in spite of a medium broad molecular weight distribution. In particular, the advantages are that the present propylene polymers can be processed at a broad range of temperatures and thus are easier processable.

A further embodiment of the present invention, relates to biaxially oriented films or sheets comprising the said propylene polymers

The advantage of laminated articles, in particular films and sheets, of the present invention is that they have good uniform thickness and also higher elongation at break and

higher tensile stress at break

The present laminated articles, in particular films or sheets are especially used in packaging of parcels, such as cigarette parcels, and in food packaging.

Therefore the present invention provides propylene polymers, preferably homopolymers, having the following features:

- 1) a content of isotactic pentads (mmmm), measured by NMR, higher than 97%, preferably higher than 97.5%, more preferably higher than 98%;
- 2) a molecular weight distribution, expressed by the M_w/M_n ratio, equal to or higher than 6, preferably from 6 to 11; and
- 3) a value of M_z/M_w equal to or lower than 5.5, preferably equal to or lower than 5, more preferably up to 4.8.

Optionally the said propylene polymers can contain minor amounts of comonomers, like ethylene or C_4 - C_{10} α -olefins (examples of which are 1-butene, 1-hexene, 3-methyl-1-pentene). Generally, when present, such comonomers do not exceed 5% by weight (preferably 2% by weight in the case of ethylene) with respect to the total weight of the polymer.

Other preferred features for the polymers of the present invention are:

- a stereoblock content up to 98 °C of 10% or lower measured by the TREF method;
- a content of fraction soluble in xylene at room temperature (about 23 °C) equal to or lower than 2.5% by weight, more preferably equal to or lower than 2% by weight;
- a P.I. (Polydispersity Index, measured as explained below) of 6 or less, more preferably of 5.5 or less, in particular less than 5;
- a value of the main elution peak temperature (measured with Temperature Raising Elution Fractionation, TREF) higher than 114 °C;
- a value of the fraction eluted up to 94 °C (TREF) equal to or lower than 5%;
- a MFRL value from 0.1 to 50 g/10 min, more preferably from 1 to 30 g/10 min;

The preferred polymers according to the present invention have a melting point of 164 °C or higher, more preferably of 165 °C or higher, such as from 165 to 168 °C.

The propylene polymers of the present invention can be obtained directly in polymerization by using a Ziegler -Natta catalyst comprising:

- a solid catalyst component comprising Mg, Ti, halogen and at least two electron donor compounds, said catalyst component being characterised by the fact that at least one of

the electron donor compounds, which is present in an amount from 15 to 50% by mol with respect to the total amount of donors, is selected from esters of succinic acids which are not extractable, under the conditions described below, for more than 20% by mol (non-extractable succinates) and at least another electron donor compound which is extractable, under the same conditions, for more than 30% by mol (extractable electron donor compounds);

- an organo-metal compound;
- a highly stereoregulating electron donor compound (outside donor).

The said catalyst component is described in WO 02/30998.

As explained above, the solid catalyst component comprises, in addition to the above electron donors, Ti, Mg and halogen. In particular, the catalyst component comprises a titanium compound, having at least a Ti-halogen bond and the above mentioned electron donor compounds supported on a Mg halide. The magnesium halide is preferably $MgCl_2$ in active form, which is widely known from the patent literature as a support for Ziegler-Natta catalysts. Patents USP 4,298,718 and USP 4,495,338 were the first to describe the use of these compounds in Ziegler-Natta catalysis. It is known from these patents that the magnesium dihalides in active form used as support or co-support in components of catalysts for the polymerization of olefins are characterized by X-ray spectra in which the most intense diffraction line that appears in the spectrum of the non-active halide is diminished in intensity and is replaced by a halo whose maximum intensity is displaced towards lower angles relative to that of the more intense line.

The preferred titanium compounds are $TiCl_4$ and $TiCl_3$; furthermore, also Ti-haloalcoholates of formula $Ti(OR)_{n-y}X_y$ can be used, where n is the valence of titanium, y is a number between 1 and n-1, X is halogen and R is a hydrocarbon radical having from 1 to 10 carbon atoms.

The preparation of the solid catalyst component can be carried out according to several methods, well known and described in the art.

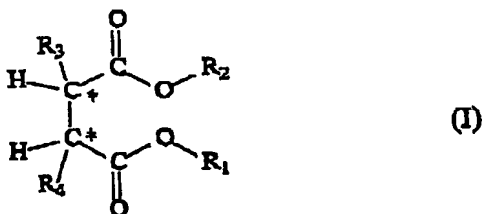
According to a preferred method, the solid catalyst component can be prepared by reacting a titanium compound of formula $Ti(OR)_{n-y}X_y$, where n is the valence of titanium and y is a number between 1 and n, preferably $TiCl_4$, with a magnesium chloride deriving from an adduct of formula $MgCl_2 \cdot pROH$, where p is a number between 0.1 and 6, preferably from 2 to 3.5, and R is a hydrocarbon radical having 1-18 carbon atoms. The adduct can be

suitably prepared in spherical form by mixing alcohol and magnesium chloride in the presence of an inert hydrocarbon immiscible with the adduct, operating under stirring conditions at the melting temperature of the adduct (100-130°C). Then, the emulsion is quickly quenched, thereby causing the solidification of the adduct in form of spherical particles.

Examples of spherical adducts prepared according to this procedure are described in USP 4,399,054 and USP 4,469,648. The so obtained adduct can be directly reacted with Ti compound or it can be previously subjected to thermal controlled dealcoholation (80-130°C) so as to obtain an adduct in which the number of moles of alcohol is generally lower than 3 preferably between 0.1 and 2.5. The reaction with the Ti compound can be carried out by suspending the adduct (dealcoholated or as such) in cold TiCl₄ (generally 0°C); the mixture is heated up to 80-130°C and kept at this temperature for 0.5-2 hours. The treatment with TiCl₄ can be carried out one or more times. The electron donor compounds can be added during the treatment with TiCl₄. They can be added together in the same treatment with TiCl₄ or separately in two or more treatments.

Regardless to the preparation method used, the final amount of the two or more electron donor compounds is such that the molar ratio with respect to the MgCl₂ is from 0.01 to 1, preferably from 0.05 to 0.5.

Among the non-extractable succinates mentioned above, particularly preferred are the succinates of formula (I) below



in which the radicals R₁ and R₂, equal to, or different from, each other are a C₁-C₂₀ linear or branched alkyl, alkenyl, cycloalkyl, aryl, arylalkyl or alkylaryl group, optionally containing heteroatoms; and the radicals R₃ and R₄ equal to, or different from, each other, are C₁-C₂₀ alkyl, cycloalkyl, aryl, arylalkyl or alkylaryl group, optionally containing heteroatoms with the proviso that at least one of them is a branched alkyl; said compounds being, with respect

to the two asymmetric carbon atoms identified in the structure of formula (I), stereoisomers of the type (S,R) or (R,S) that are present in pure forms or in mixtures.

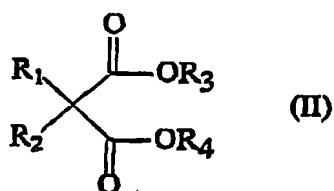
R₁ and R₂ are preferably C₁-C₈ alkyl, cycloalkyl, aryl, arylalkyl and alkylaryl groups.

Particularly preferred are the compounds in which R₁ and R₂ are selected from primary alkyls and in particular branched primary alkyls. Examples of suitable R₁ and R₂ groups are methyl, ethyl, n-propyl, n-butyl, isobutyl, neopentyl, 2-ethylhexyl. Particularly preferred are ethyl, isobutyl, and neopentyl.

Particularly preferred are the compounds in which the R₃ and/or R₄ radicals are secondary alkyls like isopropyl, sec-butyl, 2-pentyl, 3-pentyl or cycloalkyls like cyclohexyl, cyclopentyl, cyclohexylmethyl.

Examples of the above-mentioned compounds are the (S,R) (S,R) forms pure or in mixture, optionally in racemic form, of diethyl 2,3-bis(trimethylsilyl)succinate, diethyl 2,3-bis(2-ethylbutyl)succinate, diethyl 2,3-dibenzylsuccinate, diethyl 2,3-diisopropylsuccinate, diisobutyl 2,3-diisopropylsuccinate, diethyl 2,3-bis(cyclohexylmethyl)succinate, diethyl 2,3-diisobutylsuccinate, diethyl 2,3-dineopentylsuccinate, diethyl 2,3-dicyclopentylsuccinate, diethyl 2,3-dicyclohexylsuccinate.

Among the extractable electron donor compounds particularly preferred are the esters of mono or dicarboxylic organic acids such as benzoates, malonates, phthalates and succinates. Among malonates particularly preferred are those of formula (II):



where R₁ is H or a C₁-C₂₀ linear or branched alkyl, alkenyl, cycloalkyl, aryl, arylalkyl or alkylaryl group, R₂ is a C₁-C₂₀ linear or branched alkyl, alkenyl, cycloalkyl, aryl, arylalkyl or alkylaryl group, R₃ and R₄, equal to, or different from, each other, are C₁-C₂₀ linear or branched alkyl groups or C₃-C₂₀ cycloalkyl groups.

Preferably, R₃ and R₄ are primary, linear or branched C₁-C₂₀ alkyl groups, more preferably they are primary branched C₄-C₂₀ alkyl groups such as isobutyl or neopentyl groups.

R_2 is preferably, in particular when R_1 is H, a linear or branched C_3 - C_{20} alkyl, cycloalkyl, or arylalkyl group; more preferably R_2 is a C_3 - C_{20} secondary alkyl, cycloalkyl, or arylalkyl group.

Preferred esters of aromatic carboxylic acids are selected from C_1 - C_{20} alkyl or aryl esters of benzoic and phthalic acids, possibly substituted. The alkyl esters of the said acids being preferred. Particularly preferred are the C_1 - C_6 linear or branched alkyl esters. Specific examples are ethylbenzoate, n-butylbenzoate, p-methoxy ethylbenzoate, p-ethoxy ethylbenzoate, isobutylbenzoate, ethyl p-toluate, diethyl phthalate, di-n-propyl phthalate, di-n-butyl phthalate, di-n-pentyl phthalate, di-i-pentyl phthalate, bis(2-ethylhexyl) phthalate, ethyl-isobutyl phthalate, ethyl-n-butyl phthalate, di-n-hexyl phthalate, di-isobutylphthalate.

The previously said organo-metal compound is preferably chosen among alkyl-Al compounds and in particular among the trialkyl aluminum compounds such as for example triethylaluminum, triisobutylaluminum, tri-n-butylaluminum, tri-n-hexylaluminum, tri-n-octylaluminum. It is also possible to use alkylaluminum halides, alkylaluminum hydrides or alkylaluminum sesquichlorides, such as $AlEt_2Cl$ and $Al_2Et_3Cl_3$, possibly in mixture with the above cited trialkylaluminums.

Suitable outside electron-donor compounds include certain silanes, ethers, esters, amines, heterocyclic compounds and ketones. In particular, suitable highly stereoregulating silanes are comprised in the class having formula $R_a^5R_b^6Si(OR^7)_c$, where a and b are integers from 0 to 2, c is an integer from 1 to 4 and the sum $(a+b+c)$ is 4; R^5 , R^6 and R^7 are alkyl, alkylen, cycloalkyl or aryl radicals with 1 to 18 carbon atoms, optionally containing heteroatoms. Particularly preferred are the silicon compounds in which at least one of R^5 and R^6 is selected from branched alkyl and cycloalkyl groups with 3 to 10 carbon atoms and R^7 is a C_1 - C_{10} alkyl group, in particular methyl. Specific examples of preferred silanes are dicyclopentyl dimethoxysilane, tert-hexyltrimethoxysilane and diisopropyl dimethoxysilane. Dicyclopentyl dimethoxysilane is particularly preferred.

The outside donor is used in such an amount to give a molar ratio between the organoaluminum compound and said outside donor of from 0.1 to 500, preferably from 1 to 300 and more preferably from 3 to 100.

The polymerisation process can be carried out according to known techniques for example slurry polymerisation using as diluent an inert hydrocarbon solvent, or bulk polymerisation using the liquid monomer (for example propylene) as a reaction medium.

Moreover, it is possible to carry out the polymerisation process in gas-phase operating in one or more fluidised or mechanically agitated bed reactors.

The polymerisation is generally carried out at temperature of from 20 to 120 °C, preferably of from 40 to 80 °C. When the polymerisation is carried out in gas-phase the operating pressure is generally between 0.5 and 10 MPa, preferably between 1 and 6 MPa. In the bulk polymerisation the operating pressure is generally between 1 and 8 MPa preferably between 1.5 and 5 MPa.

It is particular worth noting that the said broad range of values of molecular weight distribution is obtained in a single polymerisation stage, i.e. with a substantially monomodal distribution which allows to avoid any problem due to non homogeneity of the polymer product.

According to a preferred polymerisation process the polymers of the present invention can be produced by a gas-phase polymerisation process carried out in at least two interconnected polymerisation zones. The said type of process is illustrated in European patent application 782 587.

In detail, the above-mentioned process comprises feeding one or more monomer(s) to said polymerisation zones in the presence of catalyst under reaction conditions and collecting the polymer product from the said polymerisation zones. In the said process the growing polymer particles flow upward through one (first) of the said polymerisation zones (riser) under fast fluidisation conditions, leave the said riser and enter another (second) polymerisation zone (downcomer) through which they flow downward in a densified form under the action of gravity, leave the said downcomer and are reintroduced into the riser, thus establishing a circulation of polymer between the riser and the downcomer.

In the downcomer high values of density of the solid are reached, which approach the bulk density of the polymer. A positive gain in pressure can thus be obtained along the direction of flow, so that it become to possible to reintroduce the polymer into the riser without the help of special mechanical means. In this way, a "loop" circulation is set up, which is defined by the balance of pressures between the two polymerisation zones and by the head loss introduced into the system.

Generally, the condition of fast fluidization in the riser is established by feeding a gas mixture comprising the relevant monomers to the said riser. It is preferable that the feeding of the gas mixture is effected below the point of reintroduction of the polymer into the said

riser by the use, where appropriate, of gas distributor means. The velocity of transport gas into the riser is higher than the transport velocity under the operating conditions, preferably from 2 to 15 m/s.

Generally, the polymer and the gaseous mixture leaving the riser are conveyed to a solid/gas separation zone. The solid/gas separation can be effected by using conventional separation means. From the separation zone, the polymer enters the downcomer. The gaseous mixture leaving the separation zone is compressed, cooled and transferred, if appropriate with the addition of make-up monomers and/or molecular weight regulators, to the riser. The transfer can be effected by means of a recycle line for the gaseous mixture.

The control of the polymer circulating between the two polymerisation zones can be effected by metering the amount of polymer leaving the downcomer using means suitable for controlling the flow of solids, such as mechanical valves.

The operating parameters, such as the temperature, are those that are usual in gas-phase olefin polymerisation process, for example between 50 to 120 °C.

This process can be carried out under operating pressures of between 0.5 and 10 MPa, preferably between 1.5 to 6 MPa.

Advantageously, one or more inert gases are maintained in the polymerisation zones, in such quantities that the sum of the partial pressure of the inert gases is preferably between 5 and 80% of the total pressure of the gases. The inert gas can be nitrogen or propane, for example.

The various catalysts are fed up to the riser at any point of the said riser. However, they can also be fed at any point of the downcomer. The catalyst can be in any physical state, therefore catalysts in either solid or liquid state can be used.

The usual additives, such as stabilizers and pigments, can also be added to the polymers and compositions of the present invention.

As mentioned above, the propylene polymers according to the present invention are particularly suitable to prepare films and sheets, in particular biaxially oriented films and sheets.

A further embodiment of the present invention provides laminated articles, in particular films and sheets, having improved stretchability and barrier properties, in particular moisture barrier properties. The said articles are made of polymer compositions comprising the above-mentioned polymers and a hard resin, such as polymers of coke oven gas, cracked naphtha,

gas oil and terpene oil and terpene resin. Terpene compounds are preferred. The hard resin is generally in an amount of from 0.5 to 20% by weight, preferably from 0.5 to 15%, with respect to the whole composition.

The laminated articles, i.e. films and sheets, of the present invention can be multilayered and at least one layer comprises the above-mentioned propylene polymers or compositions.

The laminated articles, i.e. films and sheets, of the present invention are obtained from the above-mentioned propylene polymers and compositions by using the well-known processes for polyolefin films/sheets production.

The following examples are given in order to illustrate but not to limit the present invention.

CHARACTERIZATIONS

Test for the extractability of the electron donor (ED) compounds

A. Preparation of the solid catalyst component

Into a 500 mL four-necked round flask, purged with nitrogen, 250 mL of TiCl_4 were introduced at 0 °C. While stirring, 10.0 g of microspheroidal $\text{MgCl}_2 \cdot 2.8\text{C}_2\text{H}_5\text{OH}$ (prepared according to the method described in example 2 of USP 4,399,054 but operating at 3,000 rpm instead of 10,000) were introduced. 4.4 mMols of the selected electron donor compound were also added.

The temperature was raised to 100 °C and maintained at that temperature for 120 min. Then, the stirring was discontinued, the solid product was allowed to settle and the supernatant liquid was siphoned off.

250 mL of fresh TiCl_4 were added. The mixture was reacted at 120 °C for 60 min under stirring and, then, the supernatant liquid was siphoned off. The solid (A) was washed six times with anhydrous hexane (100 mL each time) at 60 °C, dried under vacuum and analyzed for the quantitative determination of Mg and electron donor compound. The type of electron donor compound and its molar ratio with respect to Mg (ratio A) are reported in Table 1.

B. Treatment of solid A

In a 250 mL jacketed glass reactor with mechanical stirrer and filtration septum are introduced under nitrogen atmosphere 190 mL of anhydrous n-hexane, 19 mMmoles of AlEt_3 and 2 g of the catalyst component prepared as described in A. The mixture is heated at 60 °C for 1 hour under stirring (stirring speed at 400 rpm). After that time the mixture is

filtered, washed four times with n-hexane at 60 °C and finally dried under vacuum for 4 hours at 30 °C. The solid is then analyzed for the quantitative determination of Mg and electron donor compound. The type of electron donor compound and its molar ratio with respect to Mg (ratio B) are reported in Table 1. The extractability of the electron donor compound is calculated according to the following formula: % of ED extracted = (Ratio A - Ratio B)/Ratio A

Polymer microstructure analysis

50 mg of each xylene insoluble fraction were dissolved in 0.5 mL of $C_2D_2Cl_4$.

The ^{13}C NMR spectra were acquired on a Bruker DPX-400 (100.61 Mhz, 90° pulse, 12s delay between pulses). About 3000 transients were stored for each spectrum; mmmm pentad peak (21.8 ppm) was used as reference.

The microstructure analysis was carried out as described in literature (*Polymer*, 1984, 25, 1640, by Inoue Y. et Al. and *Polymer*, 1994, 35, 339, by Chujo R. et Al.).

Determination of xylene insoluble fraction (X.I.)

2.5 g of polymer were dissolved in 250 mL of o-xylene under stirring at 135 °C for 30 minutes, then the solution was cooled to 25°C and after 30 minutes the insoluble polymer was filtered. The resulting solution was evaporated in nitrogen flow and the residue was dried and weighed to determine the percentage of soluble polymer and then, by difference, the X.I. %.

TREF method

TREF fractionation of the polymer was carried out by dissolving 1 g of propylene polymer in o-xylene at 135°C and slowly cooling (20 h) to 25°C in a column loaded with glass beads. Elution with o-xylene (600 mL/h) was first carried out at 25 °C for 1 h to obtain a xylene-soluble fraction. The column temperature was then raised from 25 to 95 °C at a rate of 0.7 °C/min without elution and the temperature was held at 95°C for 2 h before eluting at this temperature for 1 hour to yield a single fraction. Finally, elution was continued while raising the temperature from 95 to 120 °C at a rate of 3 °C/h, collecting individual fractions at temperature intervals of 1 °C. According to the present invention the stereoblock content is considered as the total weight of the fractions, insoluble in xylene at 25 °C, that are eluted at a temperature lower than 100 °C based on the total weight of the polymer.

Melt Flow Rate L (MFRL)

Measured according to ISO 1133 (230° C, 2.16 kg).

Molecular weight (M_n , M_w and M_z)

Measured by way of gel permeation chromatography (GPC).

Determination of polydispersity index (P.I.)

This property is strictly connected with the molecular weight distribution of the polymer under examination. In particular it is inversely proportional to the creep resistance of the polymer in the molten state. Said resistance called modulus separation at low modulus value (500 Pa), was determined at a temperature of 200 °C by using a parallel plates rheometer model RMS-800 marketed by RHEOMETRICS (USA), operating at an oscillation frequency which increases from 0.1 rad/sec to 100 rad/sec. From the modulus separation value, one can derive the P.I. by way of the equation:

$$P.I. = 54.6 * (\text{modulus separation})^{-1.76}$$

in which the modulus separation is defined as:

modulus separation = frequency at $G' = 500 \text{ Pa}$ / frequency at $G'' = 500 \text{ Pa}$

wherein G' is storage modulus and G'' is the loss modulus.

Flexural modulus

Measured according to the ISO 178 method.

Izod impact resistance

Measured according to the ISO 180/1A method.

Examples 1 and 2

Preparation of solid catalyst component.

Into a 500 mL four-necked round flask, purged with nitrogen, 250 mL of TiCl_4 are introduced at 0 °C. While stirring, 10.0 g of microspheroidal $\text{MgCl}_2 \cdot 2.8 \text{C}_2\text{H}_5\text{OH}$ (prepared according to the method described in example 2 of USP 4,399,054 but operating at 3,000 rpm instead of 10,000) are introduced. As internal donors, a previously mixture of diisobutylphthalate (DIBP) and a blend of both the racemic form and meso form of diethyl 2,3-(diisopropyl)succinate (DIBIPS) are also added. The internal donor content in the solid catalyst component is shown in Table 1.

The temperature is raised to 100 °C and maintained for 120 minutes. Then, the stirring is discontinued, the solid product is allowed to settle and the supernatant liquid is siphoned off.

250 mL of fresh TiCl_4 are added. The mixture is reacted at 120 °C for 60 minutes and, then, the supernatant liquid is siphoned off. The solid is washed six times with anhydrous hexane (100 ml each time) at 60 °C.

Polymerisation

In a 4 liter autoclave, purged with nitrogen flow at 70 °C for one hour, 75 mL of anhydrous hexane containing 7 mMols of AlEt_3 , dicyclopentylmethoxysilane as external electron-donor compound (the amount is reported in the Table 1) and the solid catalyst component are introduced in propylene flow at 30 °C. The autoclave is closed, 1.5 NL of hydrogen are added and then, under stirring, 1.2 kg of liquid propylene are fed. The temperature is risen to 70 °C in five minutes and the polymerisation was carried out at this temperature for two hours. The unreacted propylene was vented, the polymer was recovered and dried at 70 °C under vacuum for three hours and, then, weighed and fractionated with o-xylene to determine the amount of the xylene insoluble (X.I.) fraction at 25 °C and its microstructure.

The polymerisation conditions are reported in Table 1.

Example 3

Example 1 is repeated with except that in the polymerisation a mixture of 70 wt% of dicyclopentylmethoxysilane and 30 wt% of cyclohexylmethyldimethoxysilane as outside electron-donor compound is used.

The polymerisation conditions are reported in Table 1.

Example 4

Example 1 is repeated except that adduct of MgCl_2 with ethanol is dealcoholated as described in example 1 of European patent application 728 769.

The polymerisation conditions are reported in Table 1.

Comparative example 1c

Preparation of solid catalyst component.

The solid catalyst component is prepared according to above example 1, except that it contains a diether, that is 9,9-bis(methoxymethyl)fluorene, as inside electron-donor compound in the place of phthalate and succinate derivatives.

The internal donor content in the solid catalyst component is shown in Table 1.

Polymerisation

The polymerisation is carried out in continuous in a series of two reactors equipped with devices for the transfer of the product coming from the reactor immediately preceding to the one immediately following.

In the gas phase the hydrogen and the monomer are analysed in continuous and fed in such a manner that the desired concentration will be maintained constant.

A mixture of triethylaluminium activator and dicyclopentylmethoxysilane as outside electron-donor compound is contacted with the solid catalyst component in a container at 40 °C for 13 minutes.

The catalyst is then transferred to a reactor containing an excess of liquid propylene and prepolymerised at 20 °C for a period ranging from 1.5 to 2 minutes ca.

The prepolymer is then transferred in another reactor where the polymerisation occurs in gas phase to form fraction (A).

The product of the above reactor is fed to a second reactor in gas phase to form fraction (B).

The polymerisation conditions are reported in Table 1.

Table 1

Example		1	2	3	4	1c
Internal electron donor	DIBIPS content wt%	4.54	6.79	6.79	4.63	0
	DIBP content wt%	12.8	11.68	11.68	6.63	0
	Diether content wt%	0	0	0	0	-
DIBIPS/DIBP molar ratio		0.35	0.63	0.63	0.75	0
Solid catalyst component fed g/h		8.2	7	6.6	6	-
AlEt ₃ /solid catalyst component g/g		10	13	14	13	6.1
AlEt ₃ /outside donor weight ratio		30	15	4	8	5.8
Polymerisation temperature °C		70	70	70	75	70

The physical and mechanical properties of the polymers of examples 1 to 4 and comparative example 1c are reported in Table 2. The mechanical properties are measured on injection-moulded samples. Examples 1-3 and comparative 1c plaques are stretched at temperatures ranging from 140 up to 155, in steps of 5°C.

(MI6041)

Table 2

Example	1	2	3	4	1c
mmmm %	>98	98.52	>98	98.61	98.43
Mw/Mn	9.2	9.6	8.7	-	-
Mz/Mw	4.2	4.1	4.8	-	-
Main elution peak temperature °C	-	114	-	117	113
Stereoblock content up to 95°C wt%	-	5.2	-	-	6.4
Stereoblock content up to 98 °C wt%	-	5.2	-	6.2	6.2
Fraction eluted up to 94 °C %	-	-	-	4.6	4.1
MFR g/10 min	3.5	3.5	2.6	2.6	3.5
Xylene-soluble fraction wt%	1.7	1.6	1.4	1.5	1.3
Polydispersity index	4.8	5	4.9	4.6	5.5
Melting temperature °C	163	163	163	165.7	162
Mechanical properties of the polymer					
Flexural Modulus MPa	1725	1770	1850	1780- 1940	1810- 1885
Izod impact resistance at 23 °C kJ/m ²	4.5	4.6	6	5.1	4.6

Example 5 and comparative example 2c

The polymer of example 4 and comparative example 1c are processed on a BOPP Stenter pilot line to produce a 20 μ plain biaxially oriented film. Polymers were extruded through a flat die as a sheet that is cooled under controlled conditions on a casting unit. After leaving the casting unit, the sheet is re-heated to an appropriate temperature and then stretched 4×1.1 in machine direction, by passing the film over a system of heated rolls running at different speeds. The stretching in transverse machine direction is achieved subsequently by a continuous drawing frame, which is enclosed in a hot air oven. The film is pre-heating in this oven (= pre-heating temperatures – as indicated in table) and then stretched 8 times in transverse machine direction by a system of chain-mounted clips moving on a diverging rail system. After the stretching, film is annealed and corona treated. Side edges are removed and finally the film is wound on a roll. Speed of the line is 70 m/min.

Table 3

Example	5	2c
Minimum oven pre-heating temperature °C	162	164
Optimum oven pre-heating temperature °C	174	174
Deviation on a 20 μ -thick film μ	1-2	0.5-3

The example 5 shows that, based on the deviation value, the film according to the present invention has a more uniform thickness than the film of the comparative example. It is also shown that the polymer can be stretched at a lower oven pre-heating temperature still obtaining an acceptable film, compared to polymer of the comparative example 2c, meaning that polymer according to the present invention is easier processable compared to the comparative polymer.

Examples 6-8 and comparative example 3c

The compositions of examples 1-3 and comparative example 1c are compression moulded into a 1.0 mm plaques and subsequently biaxially oriented on a TM (Tenter Frame) long stretching frame. The stretching occurs simultaneously at a fixed stretch ratio of 7 times in machine direction and 7 times in transverse machine direction.

Final film thickness of the biaxially oriented film is 20 μ .

Film properties are measured on the oriented film samples stretched at the optimum stretching temperature, which corresponds to 0% failure testing 5 plaques at each temperature.

The properties of the films are shown in Table 4.

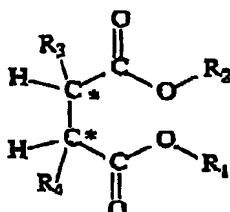
Table 4 (Bi-oriented films from stretching frame)

Example	6(2-1459)	7(2-1460)	8(2-1461)	3c(HA722J)
Elongation at break %	26	28	28	21
Tensile stress at break MPa	140	145	146	135
Tensile Modulus MPa	2970	2730	2955	3180

Films according to the present invention show a higher elongation at break and higher tensile stress at break versus comparative sample.

Claims

1. Propylene polymers having the following features:
 - 1) a content of isotactic pentads (mmmm), measured by NMR, higher than 97%,
 - 2) a molecular weight distribution, expressed by the M_w/M_n ratio, equal to or higher than 6;
 - 3) a value of M_z/M_w ratio equal to or lower than 5.5.
2. The polymers of claim 1 being propylene homopolymers.
3. The polymers of claim 1 having a stereoblock content up to 98° C of 10% or lower measured by the TREF method.
4. The polymers of claims 1 and 2 having a content of isotactic pentads higher than 97.5%.
5. The polymers of claims 1 to 3 having a molecular weight distribution from 6 to 11.
6. The polymers of claims 1 to 4 having a value of M_z/M_w equal to or lower than 5.
7. The polymers of claims 1 to 5 having a melting temperature of 164 °C or higher.
8. The polymers of claims 1 to 6 obtainable by a process carried out in only one polymerisation stage and in the presence of a Ziegler -Natta catalyst comprising:
 - a solid catalyst component comprising Mg, Ti, halogen and at least two electron donor compounds, said catalyst component being characterised by the fact that at least one of the electron donor compounds, which is present in an amount from 15 to 50% by mol with respect to the total amount of donors, is selected from esters of succinic acids which are not extractable, under the conditions described below, for more than 20% by mol (non-extractable succinates) and at least another electron donor compound which is extractable, under the same conditions, for more than 30% by mol (extractable electron donor compounds);
 - an organo-metal compound;
 - a highly stereoregulating electron donor compound (outside donor).
9. The polymers of claim 7 wherein the esters of succinic acids are selected from the succinates of formula (I) below



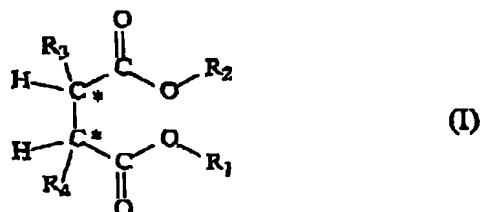
(I)

in which the radicals R_1 and R_2 , equal to, or different from, each other are a C_1 - C_{20} linear or branched alkyl, alkenyl, cycloalkyl, aryl, arylalkyl or alkylaryl group, optionally containing heteroatoms; and the radicals R_3 and R_4 equal to, or different from, each other, are C_1 - C_{20} alkyl, cycloalkyl, aryl, arylalkyl or alkylaryl group, optionally containing heteroatoms with the proviso that at least one of them is a branched alkyl; said compounds being, with respect to the two asymmetric carbon atoms identified in the structure of formula (I), stereoisomers of the type (S,R) or (R,S) that are present in pure forms or in mixtures.

10. The polymers of claims 7 and 8 wherein the other electron-donor compound in the solid catalyst component is selected from...
11. The polymers of claims 7 to 9 wherein the outside electron-donor compound is selected from of silanes of formula $R_a^5 R_b^6 Si(OR^7)_c$, where a and b are integers from 0 to 2, c is an integer from 1 to 4 and the sum (a+b+c) is 4; R^5 , R^6 and R^7 are alkyl, alkylen, cycloalkyl or aryl radicals with 1 to 18 carbon atoms, optionally containing heteroatoms.
12. A process for preparing the polymers of claim 1 comprising only one polymerisation stage conducted in the presence of a Ziegler -Natta catalyst comprising:
 - a solid catalyst component comprising Mg, Ti, halogen and at least two electron donor compounds, said catalyst component being characterised by the fact that at least one of the electron donor compounds, which is present in an amount from 15 to 50% by mol with respect to the total amount of donors, is selected from esters of succinic acids which are not extractable, under the conditions described below, for more than 20% by mol (non-extractable succinates) and at least another electron donor compound which is extractable, under the same conditions, for more than 30% by mol (extractable electron donor compounds);
 - an organo-metal compound;
 - a highly stereoregulating electron donor compound (outside donor).

(MI6041)

13. The process of claim 11 wherein the esters of succinic acids are selected from the succinates of formula (I) below



in which the radicals R_1 and R_2 , equal to, or different from, each other are a C_1 - C_{20} linear or branched alkyl, alkenyl, cycloalkyl, aryl, arylalkyl or alkylaryl group, optionally containing heteroatoms; and the radicals R_3 and R_4 equal to, or different from, each other, are C_1 - C_{20} alkyl, cycloalkyl, aryl, arylalkyl or alkylaryl group, optionally containing heteroatoms with the proviso that at least one of them is a branched alkyl; said compounds being, with respect to the two asymmetric carbon atoms identified in the structure of formula (I), stereoisomers of the type (S,R) or (R,S) that are present in pure forms or in mixtures.

14. The process of claims 11 and 12 the other electron-donor compound in the solid catalyst component is selected from...
15. The process of claims 11 to 13 wherein the outside electron-donor compound is selected from of silanes of formula $R_a^5 R_b^6 Si(OR^7)_c$, where a and b are integers from 0 to 2, c is an integer from 1 to 4 and the sum (a+b+c) is 4; R^5 , R^6 and R^7 are alkyl, alkylen, cycloalkyl or aryl radicals with 1 to 18 carbon atoms, optionally containing heteroatoms.
16. Films or sheets comprising the polymer of claims 1 to 7.
17. Films or sheets comprising a composition comprising the polymer of claims 1 to 7 and a hard resin.
18. Multilayer laminated articles comprising the film or sheet of claims 16 or 17.

Abstract

Propylene polymers having a content of isotactic pentads (mmmm), measured by NMR, higher than 97%, a molecular weight distribution, expressed by the M_w/M_n ratio, equal to or higher than 6 and a value of M_z/M_w ratio equal to or lower than 5.5.

The said polymers are prepared in the presence of a particular combination of Ziegler-Natta solid catalyst components and highly stereoregulating electron-donor compounds.

Laminated articles, in particular bi-axially oriented films and sheets can be prepared with the said polymers.

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